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Polarisation Control Mechanism of DFB Fibre Lasers

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Published in:
Lasers and Electro-Optics Europe, 1998. 1998 CLEO/Europe. Conference on

Publication date:
1998

Document Version
Publisher's PDF, also known as Version of record

12.15 CTuF6

Single-polarisation operation of injection locked fibre DFB lasers

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Optical fibre distributed-feedback (DFB) lasers using UV-written fibre Bragg gratings on Er^{3+}:Yb^{3+} fibres feature single-frequency operation, thus are a promising technology for applications in optical fibre communications[1]. Most fibre DFB lasers, however, actually operate in two orthogonal polarisations as a result of polarisation independence in the fibre DFB resonator, which is not desirable for these applications. In this paper, we report single-polarisation operations of fibre DFB lasers using injection locking techniques, which are similar to those used for polarisation switching in He-Ne lasers[2].

The configuration of the injection locked fibre DFB laser is shown in Fig.1. The fibre DFB laser is pumped with a 980nm pump laser diode (LD) through a WDM coupler, and the lasing light is output through the WDM coupler and an isolator. A single-frequency (f_i), single-polarisation signal from a tunable LD is fed to another end of the DFB laser through a polarisation controller (PC) and an isolator. Without injection, the DFB laser operated at 1548.7nm, and in two polarisations (denoted by x and y) at different frequencies (f_x and f_y) separated by 0.8GHz.

Figure 2 shows the RF spectra obtained by direct detection of the laser output. In Fig.2(a), the light was injected but the DFB laser was not locked. A line at 0.8GHz is a beat between f_x and f_y, and lines at 0.1GHz and 0.9GHz are beats between f_i and f_x and between f_i and f_y, respectively. When f_i was set closer to f_x, the DFB laser was injection locked, i.e. f_x was locked to f_i, and the beats between f_x and f_y and between f_i and f_y disappeared, as shown in Fig.2(b), which means that the y-polarisation was suppressed by injection locking. We confirmed using a polarisation analyzer that, when f_x was locked to f_i, the output was in x-polarisations, regardless of the polarisation state of injected light. That was also true when f_y was locked to f_i. The injection locking range was found to be around 10MHz at the injection power of 0.2mW, which is very narrow compared with that of DFB LDs (typically a few GHz), probably due to much longer length of the fibre DFB laser(~5cm). As the locking range was below the frequency stability of injected light, the locking behavior was unstable.

As a simpler and more stable method to achieve single-polarisation operation, we tried the self-injection locking technique, in which one of two polarisation is feedback to the DFB laser, as shown in Fig.3. A polarizer and a mirror are used, and two PCs are inserted between the DFB laser and the polarizer (PC1), and between the polarizer and the mirror (PC2), respectively. We can select either of the two polarisations to be locked by adjusting the PC1.

Figure 4 shows the RF spectra obtained by heterodyne detection of the laser output with a light from the tunable LD. Without self-injection, two beat lines were observed corresponding to f_x and f_y separated by 0.8GHz, as shown in Fig.4(a). With self-injection, only f_x was locked and f_y was suppressed (Fig.4(b)). By adjusting the PC1, we could also select f_y. We found that this operation was very stable.

References [1] W. H. Loh, et al., J. Lightwave Technol., vol.16, no.1, pp.114-118, Jan. 1998. [2] S. T. Hendow, et al., Opt. Lett., vol.7, no.8, pp.356-358, Aug. 1982.

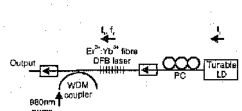

Fig.1 Injection locked fibre DFB laser.

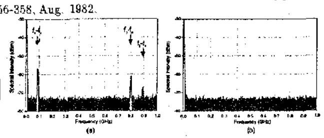
Fig.2 RF spectra. (a) Unlocked (b) locked ($f_i = f_x$)

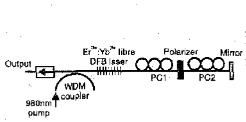

Fig.3 Self-injection locked fibre DFB laser.

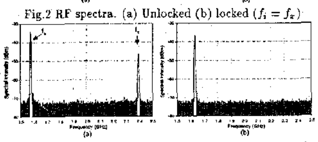
Fig.4 RF beat spectra. (a) No injection (b) locked to f_x

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Polarisation control mechanism of DFB fibre lasers

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Since the introduction of single-mode DFB fibre lasers with UV induced phase-shift, these lasers have found many applications within optical communication [1]. Single polarisation operation of the laser could be attributed to a polarisation dependence of either the grating reflectivity, background loss, erbium gain, or the phase-shift. It has been shown that a birefringent distributed phase-shift causes a considerable difference in the magnitude of the phase-shift experienced by the two polarisations [2]. However, until now it has not been clarified which polarisation dependent effect is dominating in obtaining single polarisation operation. In this paper, we present experimental evidence that a birefringent distributed phase-shift is the dominating effect.

A Bragg grating was written in an erbium doped fibre using a KrF excimer laser. The UV induced birefringence was around $2 \cdot 10^{-5}$. A distributed phase-shift was induced by exposing the centre part of the Bragg grating to additional UV pulses through a 4 mm aperture. After 1500 pulses of this UV post-processing (UVPP), single polarisation lasing was obtained when the Bragg grating was pumped by a diode laser. Continuing the UVPP, the lasing was shifted three times between orthogonal polarisation states as shown in Fig. 1. The reversible behaviour indicates that the lasing polarisation mode is not controlled by a polarisation dependent loss mechanism. Single longitudinal mode operation was observed throughout the experiment using a scanning Fabry-Perot interferometer. The lasing polarisation modes were related to the transmission peaks in the Bragg grating caused by the phase-shift. The phase-shift is polarisation dependent and the difference is controlled by the birefringence of the UV-induced index change. An index change of $2 \cdot 10^{-4}$ in the 4 mm phase-shift region is required for obtaining a grating phase-shift of π. Throughout the UVPP we observed excellent agreement between the position of the transmission peaks and the power of the corresponding lasing polarisation modes. Single polarisation lasing was observed when only one polarisation peak was positioned near the centre of the Bragg grating.

In conclusion we have demonstrated that the polarisation of a single-mode DFB fibre laser can be controlled by the birefringence of the UV induced phase-shift.

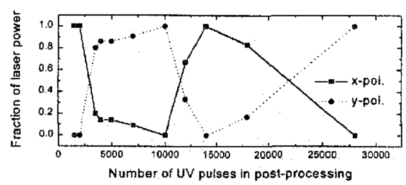

Figure 1: Evolution of the fraction of power in the x- and y-polarisation during UV post-processing

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[2] H. Storøy, B. Sahlgren and R. Stubbe, "Single polarisation fibre DFB laser", Electronics Letters, Volume 33, Number 1, Pages 56-57,1997.